Part II

General Description of the BTeV Detector

Contents

Chapter 2

Description

The BTeV detector is shown schematically in Fig. 2.1. The covered angular region is from approximately 10 mr to 300 mr with respect to the anti-proton beam. The main reasons to choose the forward direction are described in Chapter 1. Briefly, both the produced B and the $\overline{B}$ have a large probability of both being in the acceptance. Furthermore, the B momenta are large enough that the charged decay products are not degraded by multiple scattering in the detector material, which allows accurate determinations of B decay vertices. Fig. 2.2 shows the B momentum distribution (p_B) for a sample of $B^o \to \pi^+\pi^-$ decays after all analysis and trigger selections. It also shows the error in the decay vertex as a function of momentum. The peak of the B^o momentum distribution is about 30 GeV/c. Since the average decay length goes as 480 μm$\times p_B/m_B$, 30 GeV/c B's go about 3 mm. Below about 20 GeV/c the error on measuring the decay distance grows, while above 30 GeV/c the decay distance error grows linearly with B momentum. The error growth at low momentum is due to multiple scattering. Since the key variable is decay distance divided by the error on decay distance, L/σ, it is best to have B's above 20 GeV/c. L/σ is key in triggering as well as rejecting background. We note that central detectors such as CDF and D0 are generally working with B's below 20 GeV/c while LHCb is using B's well above 50 GeV/c, but gains no advantage in L/σ with respect to BTeV.

The key design features of BTeV include:

- A dipole centered at the interaction region placing magnetic field on the vertex detector allowing the use of momentum determination in the trigger. There are two open ends of the magnet. One open end allows particles to flow into the instrumented "arm." The field is used by the tracking system to provide precise momentum determinations of all of the charged particles.

- A precision vertex detector based on planar pixel arrays. The pixels are used to trigger on detached heavy quark decay vertices in the first trigger level. They also provide precise and unambiguous three-dimensional space points for the charged particle tracking;

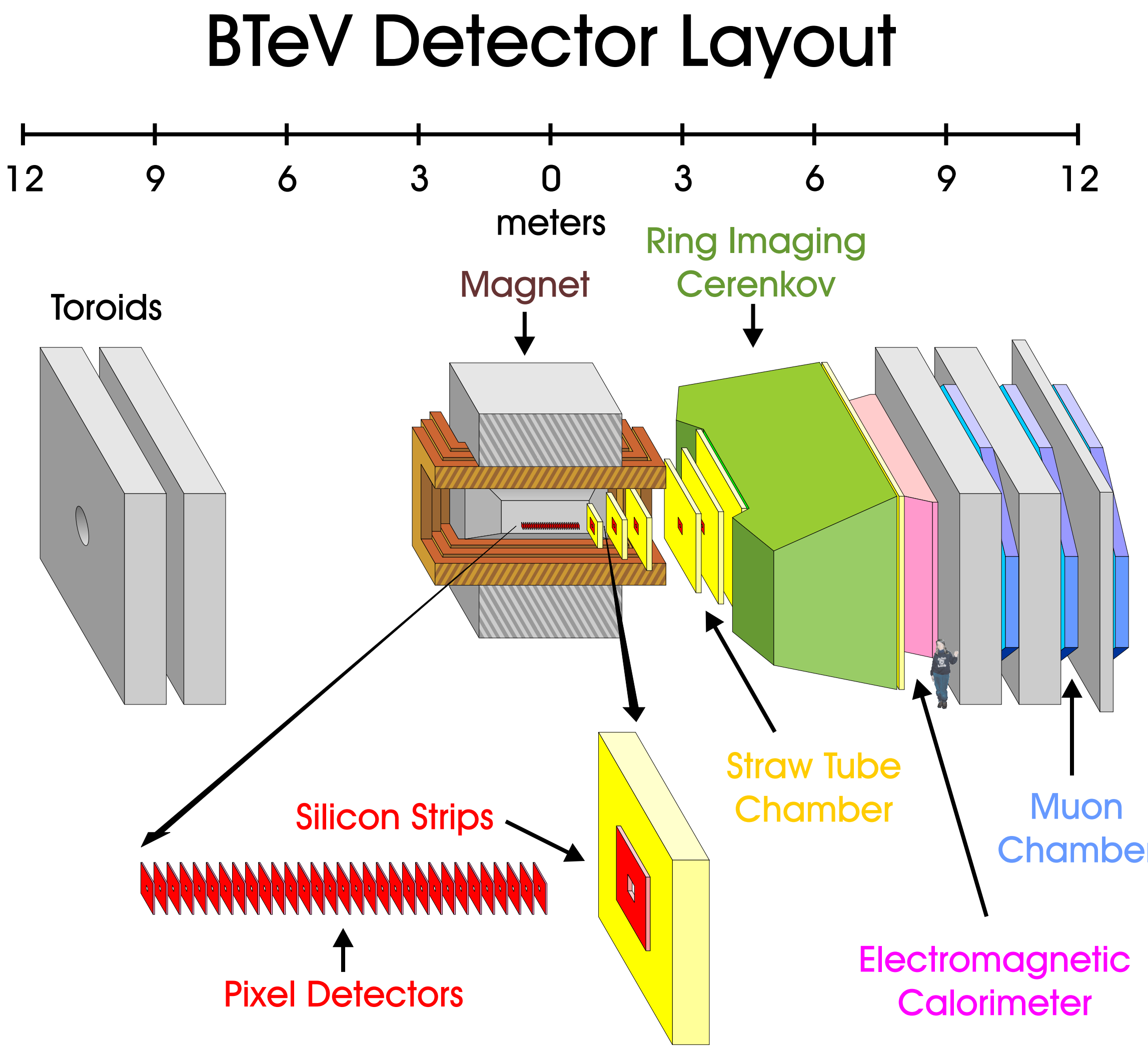

Figure 2.1: Layout of the BTeV Detector

- Precision tracking using a combination of straw tubes and silicon microstrip detectors, inside the straws close to the beam line, where the charged particle occupancies are the largest. This system when coupled with the pixels provides excellent momentum and mass resolution out to 300 mr;
- Excellent charged particle identification using a Ring Imaging Cherenkov Detector (RICH). The RICH provides hadron identification from 3-70 GeV and lepton identification from 3-20 GeV, out to the full aperture of 300 mr, which is crucial since the muon detector and calorimeter do not cover the full solid angle. The RICH has two independent systems sharing the same space. One has a gas (C_4F_8O) radiator and a Multianode Photomultiplier photon detector and the other has a liquid C_5F_{12} radiator and a Phototube photon detector. Both systems work in the region of visible light;

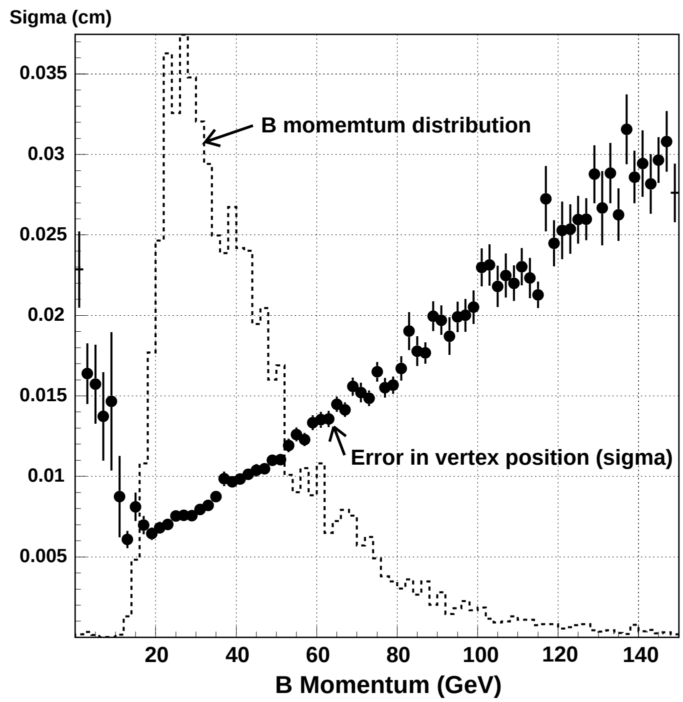

Figure 2.2: Distribution of B momenta in selected $B^o \to \pi^+\pi^-$ decays (dashed) and the error (σ) in determination of the distance the B^o traveled from the production to the decay point (solid).

- A high quality $PbWO_4$ electromagnetic calorimeter with excellent energy resolution, position resolution and segmentation, covering up to 200 mr, capable of reconstructing final states with single photons, π^o's, η's or η''s, and identifying electrons;

- Excellent identification of muons out to 200 mr using a dedicated detector consisting of a steel toroid instrumented with proportional tubes. This system has the ability to both identify single muons above momenta of about 10 GeV/c and supply a dimuon trigger;

- A detached vertex trigger at Level 1, using the pixel detector, which makes BTeV efficient for most final states, including purely hadronic modes. The trigger discriminates against low momentum tracks that have large multiple scattering and would thereby create false vertices; and

- A very high speed and high throughput data acquisition system which eliminates the need to tune the experiment to specific final states.

Fig. 2.1 shows toroidal magnets on both sides of the interaction region. The one on the un-instrumented side has two purposes. One is to provide shielding and the other is to provide symmetrical magnetic excitations to the Tevatron beams in case running with only the system in the instrumented arm excited causes problems for the machine.

A detailed description of each part of the detector is given in the next part of this report. The level of detail is sufficient to provide the reader with a good overview of the experimental apparatus and a reasonable understanding of the solutions to all the various problems associated with carrying out our ambitious program of studying B decays. We try to present enough detail that an expert would need to understand the implementation and status of the development of each detector technology and to evaluate our cost estimate and schedule. However, we do not provide complete engineering drawings for every component, nor do we discuss the many calculations that went into the optimization of the design. Additional information may be found in the many reports, which are referenced in the text.

The physics case for BTeV is presented in the BTeV Conceptual Design Report [1].

Bibliography

[1] BTeV Document 2058:

http://www-btev.fnal.gov/cgi-bin/DocDB/ShowDocument/docid=2058